MAP-doc-4312

October 13, 2011

MUON ACCELERATOR PROGRAM

ACCOMPLISHMENTS IN FY11

1. INTRODUCTION

This document summarizes the main MAP accomplishments of FY11. It is not meant as a comprehensive report, but highlights major achievements in the first year of MAP. The distribution of resources that led to these accomplishments is shown in Appendix 1.

2. PRIORITIES

In executing the FY11 plan, resources were allocated based upon the following priorities:

- Preparing for MICE: Spectrometer & RFCC Solenoids.
- Exploring high gradient RF operation in magnetic fields.
- Simulation studies that inform and guide the MAP component R&D.
- Preparing the way for selected future high priority critical component development.

To the extent that resources allowed, emphasis was also given to critical R&D at the interface to, or in collaboration with, national and international efforts external to MAP. These selected and leveraged activities included (i) machine-detector interface studies to support a small but effective external Muon Collider (MC) physics and detector study group, (ii) studies with the Project X team to understand how Project X might be upgraded to serve a MC, (iii) studies for the Interim Report for the International Design Study for a Neutrino Factory, and (iv) in collaboration with the VHFSMC and SBIR supported programs, exploring the path to the very high field HTS solenoids needed for the last few stages of a MC muon ionization cooling channel.

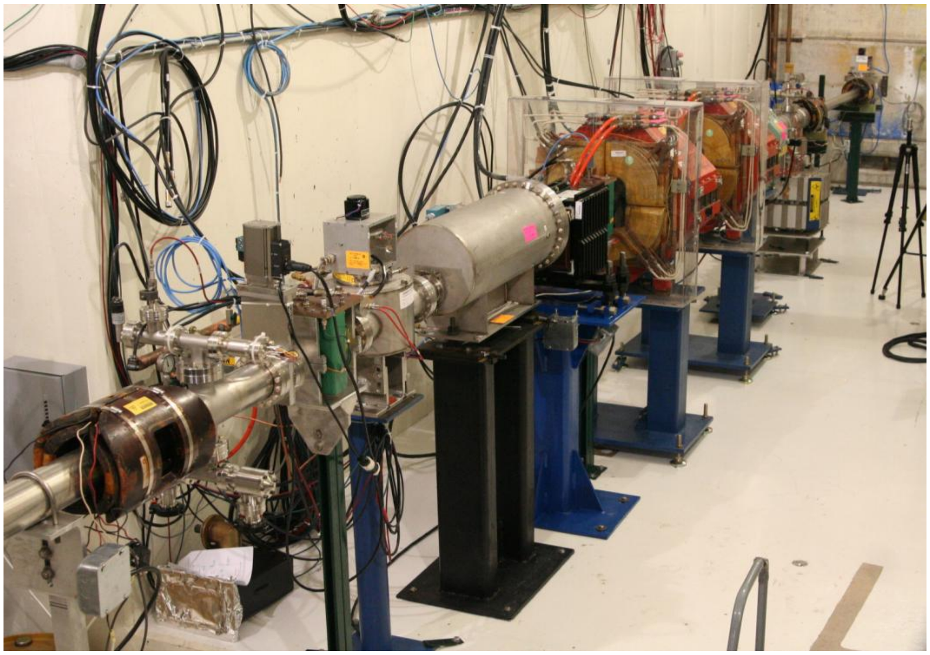


Figure 1: The new MuCool Test Area (MTA) beamline, completed and commissioned in FY11.

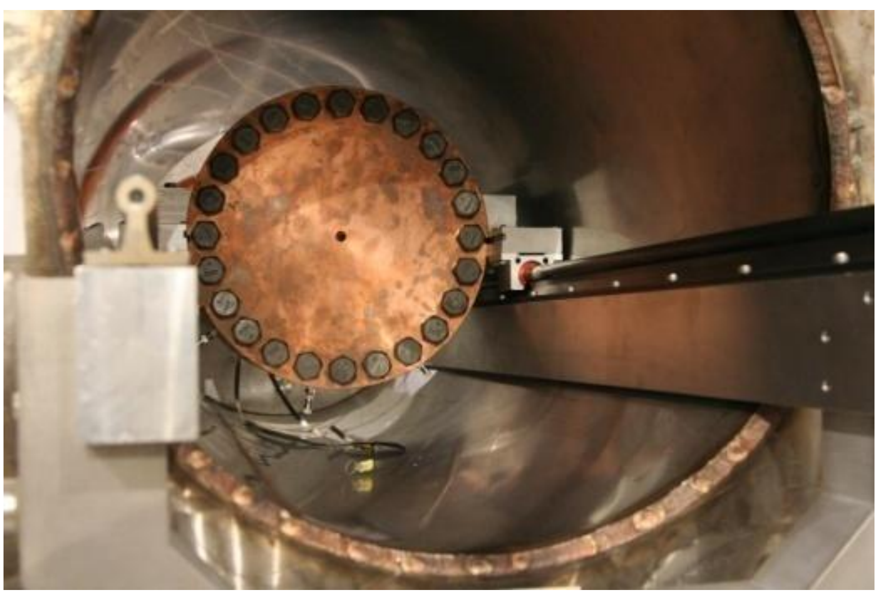


Figure 2: High Pressure RF (HPRF) cavity located inside the bore of the MuCool 5T solenoid. The cavity was successfully tested with beam in FY11.

3. ACCOMPLISHMENTS

3.1 Organization

The MAP management plan was completed and signed by all parties in March 2011. The plan is based on an organization that, in response to the recommendations from the review of the MAP proposal at the end of FY10, has been streamlined. The organization chart is shown in Appendix 2. The review committee also recommended the formulation of a MAP mission statement. The resulting mission statement is shown in Appendix 3. Further details about the organization, meetings, and documentation can be found from the new MAP webpage: http://map.fnal.gov/ . Publications produced in FY11 as a result of MAP R&D are listed in Appendix 4.

3.2 RF R&D

The focus of the MAP RF R&D is to find an RF technology that can provide the required accelerating gradients within the magnetic fields needed for a muon ionization cooling channel. The candidate technologies are tested in a unique accelerator R&D facility at Fermilab: the MuCool Test Area (MTA).

The main FY11 RF R&D achievements are:

- **Beam was successfully established in the MTA**. The MTA had been effectively shut down from 2008 to 2010 to prepare the facility for beam operations. In FY11 the MTA was brought back into full operation, with its capabilities enhanced by the addition of a new beamline from the Fermilab linac (Fig. 1). The MTA beamline was commissioned, and the first measurements with a gas-filled cavity operating in the beam were completed (see below).

- **High pressure hydrogen filled cavities were tested in a beam for the first time.** One of the candidate cooling channel technologies consists of RF cavities filled with high pressure hydrogen gas. Past studies have shown that these cavities can provide the required gradients within a few Tesla magnetic field when no beam is present. In FY11 the first test of this technology in a beam was made at the MTA (Fig. 2). Results are encouraging. The beam ionizes the gas, and the released electrons drain energy from the RF field until they are captured. In pure hydrogen the ionization electrons live too long, and the RF field collapses. However, the measurements showed that this effect is greatly mitigated with the addition of a small amount of electronegative impurity. Further studies will reveal whether the level of mitigation is sufficient. Measurements must also be made with both beam and magnetic field.

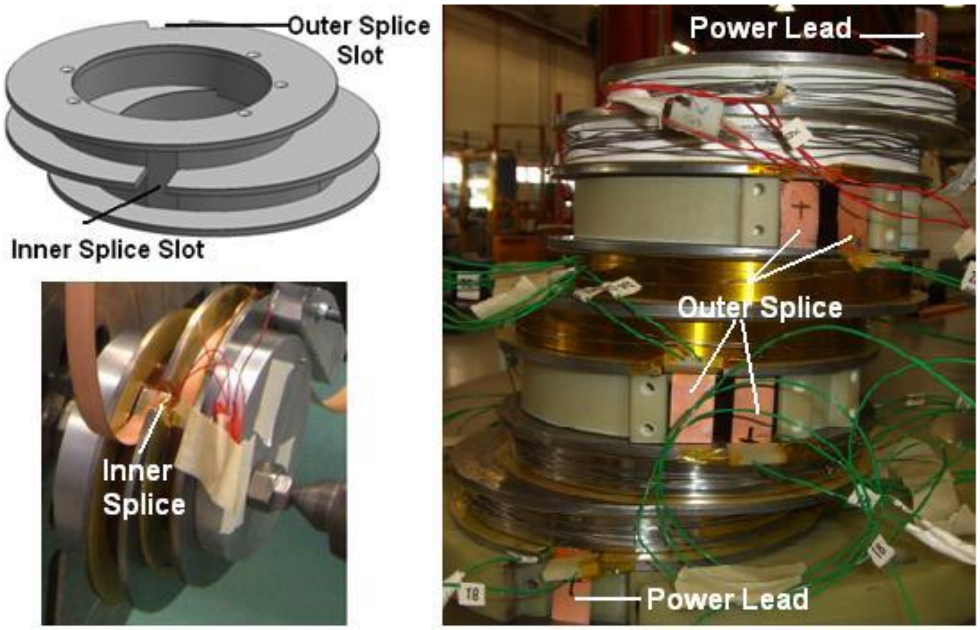


Figure 3: Fabrication of double pancake sections of the HTS Helical Solenoid (HS) model made of 12 mm YBCO tape. In FY11 this was successfully tested at 77 K and 4.2 K in the FNAL SC R&D lab.

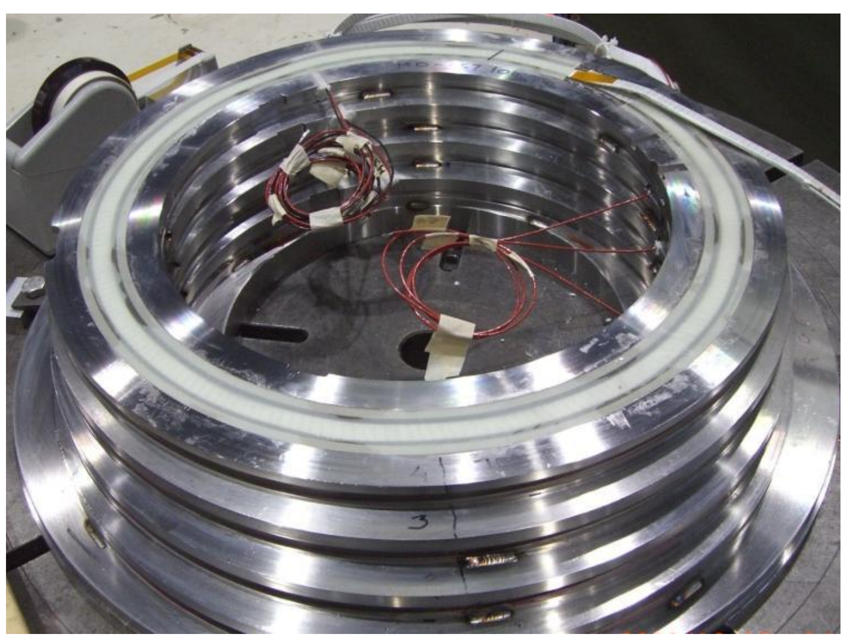


Figure 4: Helical Cooling Channel (HCC) model magnet, fabricated and tested in FY11 to understand feasibility and issues associated with this type of cooling channel lattice.

- **Magnetic insulation was eliminated from the candidate list.** A second candidate cooling channel technology consisted of operating vacuum copper cavities in a magnetic lattice designed so that the magnetic field is parallel to the cavity surface at places of high surface gradient. In FY11 an 805 MHz box-cavity was built to test this "magnetic insulation" idea. The cavity was designed so that it could be rotated within the MTA 5 T solenoid. The measurements showed that although higher gradients could be achieved when the cavity was operated in the field with exactly the right orientation, the improvement was not sufficient and rapidly disappeared when the angle was changed by only a few degrees. It is now understood that although the accelerated dark current electrons are guided away from high-gradient surfaces, local breakdowns survive far longer in this configuration and end up still causing trouble. With this better understanding, magnetic insulation has been eliminated from our candidate list.

- **Cavity design work was advanced to prepare for the critical FY12 cavity tests.** Each year, progress with the RF technology testing depends upon completing the appropriate test cavity designs and/or fabrication in the prior year. In FY11 design work for two important future cavities was advanced: (i) A preliminary engineering design of a beryllium-wall cavity was completed. We have some evidence, based on operating cavities in magnetic fields with beryllium windows, that a beryllium walled cavity may achieve the desired accelerating gradients in a few Tesla field. Testing a cavity of this type is a high priority. (ii) Design of a new 805 MHz copper cavity has begun. In the MAP review at the end of FY10 it was pointed out that our knowledge of RF operation in magnetic fields was based on very limited cavity statistics, and that we need to test more cavities. To follow this recommendation, a new cavity has been designed at SLAC, and will be fabricated in FY12 using standard SLAC procedures, and then tested in the MTA.

3.3 MAGNET R&D

The focus of the FY11 MAP magnet R&D was to prepare the way for selected future high priority critical component development.

The main FY11 magnet R&D achievements are:

- **A four double-pancake YBCO coil was assembled and produced a bore field of 21.2 T.** Solenoids that are beyond the current state of art are crucial for the last few stages of a MC cooling channel. The final luminosity is approximately proportional to the field in these last cooling stages. To obtain luminosities $O(10^{34})$ cm^{-2} s^{-1} requires fields of 30 T or more. HTS offers the possibility of developing solenoids that can provide these fields. In FY11 MAP R&D within the Fermilab Technical Division successfully tested a double pancake YBCO coil that produced a maximum field of 18.2 T (~ 100% of the short sample limit) at 4.2 K in a background of 13.5 T (Fig. 3). Later, a coil made of four double pancakes was assembled. A maximum field of 21.5 T (21.2 T in the bore) was produced at 4.2 K in a 14 T background field. This corresponded to a coil self-field of ~9 T and roughly 92% of the expected short sample limit. This R&D complemented other YBCO development supported through the DOE SBIR program. A second promising conductor technology, BSCO-2212, is being explored by the DOE supported VHFSMC. MAP leadership is in close contact with the leadership of these other activities, and future joint plans are being developed to push forward the R&D towards prototyping 30 T cooling channel solenoids within a few years.

- **HCC Model Studies were successfully completed.** One promising cooling channel lattice, the helical cooling channel (HCC), requires a solenoid with superimposed helical dipole, quadrupole, and sextupole fields. A design, using short circular coils equally spaced along the *z* axis – with the center of each coil shifted in the transverse plane so as to follow the helical beam orbit – has been developed at Fermilab. The second model of this design (Fig. 4) was completed in June 2010, and the magnet was tested in two cold-test cycles in November and December 2010. The performance was improved over the first model, with better coil insulation and superconducting lead support. These results will inform an important choice that must be made once an RF technology has been identified that can deliver the required cooling channel gradients within a few Tesla magnetic field. We then anticipate choosing an appropriate cooling channel design and prototyping and bench testing a short section. Other competing cooling channel lattices are more conventional, and do not need this preparatory work prior to the choice.

- **A Model Rapid Cycling Magnet capable of getting to 1.8 T at 400 Hz was demonstrated.** The cost of the acceleration complex is an important consideration for any future lepton collider. If the main acceleration for a MC can be accomplished with one or more rapid cycling synchrotrons (RCS) the cost is likely to be much less than using RLAs. However, the required RCS will need rapid cycling magnets that are beyond the state-of-art. To provide a proof-of-principle demonstration that these magnets are feasible, in FY11 a dipole magnet using 0.011" AK Steel (TRAN-COR H-1) grain oriented silicon steel laminations was constructed, together with a suitable power supply. With 53 turns of copper wire, a field of 1.88 T and a period of 1.81 milliseconds (550 Hz) was observed when applying 600 volts, meeting the demonstration goal.

Figure 5: MICE Scintillating Fiber tracker taking data in a cosmic ray test stand. In FY11 operation of the tracker was re-established ready for installation in FY12. The readout for this detector is a MAP responsibility.

Figure 6: MICE Spectrometer Solenoid. Making a plan to modify this solenoid was a high priority for MAP in FY11.

3.4 MICE

The main focus of the MAP FY11 MICE activities was to recover from the problems that have been encountered with the completion of the Spectrometer Solenoids and the RFCC Solenoids. The first and crucial steps in this recovery have been to (i) understand what needs to be done to successfully repair the Spectrometer Solenoids, (ii) create an agreed upon "Spectrometer Solenoid Modification Plan", (iii) understand whether we need to change the plan of testing the first RFCC module coupling coil in China, and having decided that we do, (iv) create a viable plan to make this critical test in the U.S.

- **The MICE Spectrometer Solenoid Modification Plan was finalized**. Prior to MAP, the MICE Spectrometer Solenoids (Fig. 6) had been designed and built. During the period that the MAP R&D plan was being formulated, these magnets were tested. They did not meet their operational requirements, and therefore a critical part of the MAP plan was to understand the limitations of the original design, and to create and execute, as quickly as practical, an appropriate modification plan. In FY11 detailed calculations were performed to provide an adequate understanding of what needed to be fixed, and a modification plan was created, documented and internally reviewed. Based on this plan, we expect to deliver the modified magnets to MICE in the second half of FY12.

- **A viable MICE Coupling Coil Test Plan was created**. For MICE Steps V and VI (as well as for 201 MHz cavity testing in the MuCool Test Area), the critical magnets are the Coupling Coil (CC) solenoids, which are necessarily large in order to surround the 201 MHz RF accelerating cavities used in MICE. The first (MuCool) CC cold mass has been wound by the Qi Huan Co. in Beijing. The original plan — testing the first coil at the (MICE-collaborating) Harbin Institute of Technology (HIT) — has accrued substantial delay due to lack of the foreseen manpower at HIT. Testing the first coil is now on the critical path, and to avoid further delays to MICE, in FY11 it was decided to ship the first coil to the U.S. and test it at Fermilab. It is currently being shipped to LBNL. A testing and integration plan for it is under development. A suitable existing test cryostat has been found and shipped to Fermilab from the NHMFL in Florida. Executing the plan to test the coil in the TD at Fermilab will be a crucial FY12 activity for MAP.

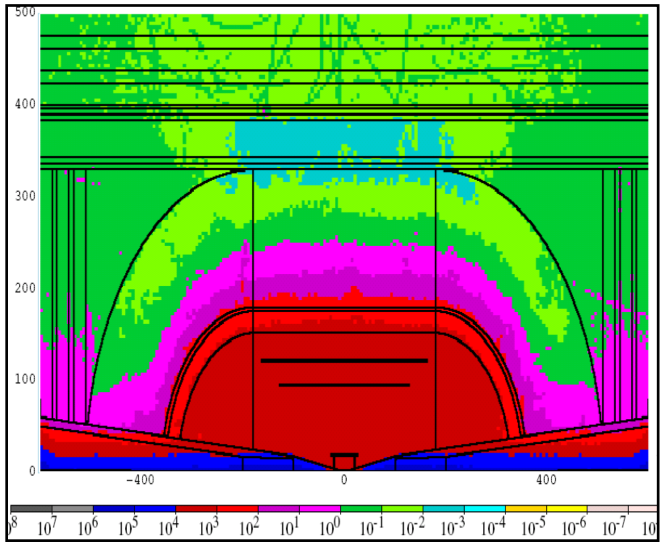


Figure 7: Simulation of particle densities at the interaction point of a 1.5 TeV Muon Collider produced by beam backgrounds. Files of the background particles, generated using the MARS code, are made available for detector background studies. In FY11 this resulted in significant progress in understanding the backgrounds and the detector requirements.

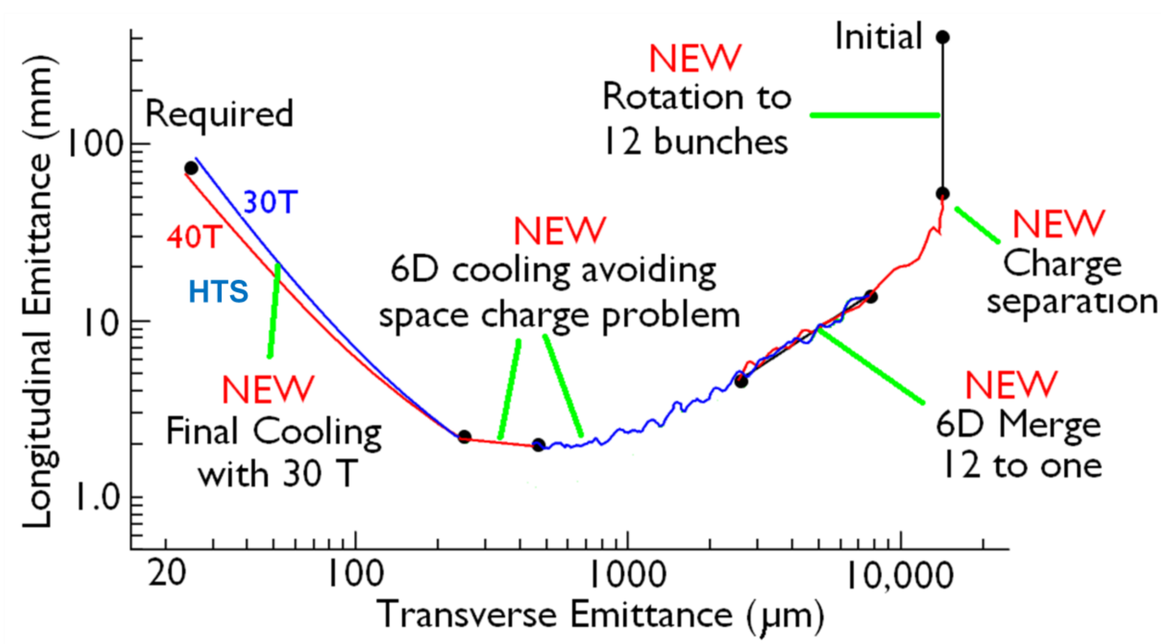


Figure 8: Simulation results for the performance of a Muon Collider Cooling channel showing the path through 6D phase space that the muon beam follows in response to the channel. The "NEW" labels indicate that progress has been made in every part of the channel, including how to separate the muon charges when needed, how to merge the bunch train into a single bunch, how to avoid longitudinal space charge problems, and how to reduce the magnitude of the solenoid field needed for the final cooling.

3.5 DESIGN AND SIMULATION

The focus of the FY11 MAP design and simulation activities was to better understand the component requirements for ionization cooling channels and the collider ring, compile an overall parameter list for a Muon Collider, and to interface with some important external efforts (MC physics and detector studies, Project X studies, and the International Design Study for a NF).

The main FY11 design and simulation achievements are:

- **A plausible path was identified to enable PROJECT X to be upgraded to serve as the front end of a MC**. To obtain sufficient luminosity, a MC requires, in present designs, a 4 MW proton source. Obtaining this beam power with an upgraded Project X design is straightforward, but the challenge is that the MC requires these protons to be packaged into a few very short (~2 ns) bunches. It was not obvious how to do this, so in FY11 a joint Task Force was created between MAP and the Project X team to explore how the design of Project X might be upgraded to meet the requirements of the MC. A scenario has been outlined by the Task Force for producing the required MC bunch structure using accumulator and compressor rings following the 8 GeV pulsed linac.

- **A MC detector shielding design was successfully implemented in MARS and detailed detector background files were generated.** External to MAP, a modest but effective MC physics and detector activity has been pursued, with strong coordination between its leadership and the MAP leadership. To support the detector studies, a Machine-Detector Interface group within MAP optimizes the final focus including the detector shielding configuration, and generates background files for detector studies. In FY11 this has resulted in significant progress on understanding the detector requirements, as reported and discussed in the MC2011 workshop in Telluride in July.

- **A first MC component parameter list was produced tabulating RF and magnet systems and permitting an estimate of the total wall plug power.** A recommendation from the review of the MAP proposal in FY10 was to produce a list of the RF cavities, power etc needed in the baseline end-to-end MC design. Although the design work is at an early stage with important choices still to be made, it is sufficiently advanced to make a first attempt at compiling a parameter list for the main components (RF and magnets) and making a first estimate of the total wall plug power needed for a multi-TeV MC. This first attempt was completed in FY11.

- **Improved cooling channel design studies yielded a better understanding of cooling channel component performance requirements, and enabled the previous 50 T goal for the final solenoids to be relaxed to 30-40 T.** Prior to FY11 it appeared that, to meet the MC design luminosity goal, the corresponding amount of ionization cooling would require 50 T solenoids in the final stages of the cooling channel. Further design and simulation work has resulted in an improved design that enables the solenoid field requirement to be relaxed to 40 T, and possibly even to 30 T. In addition, following the recommendations from the MAP proposal review, work also focused on space charge effects in the cooling channel, and this work has resulted in a revised design for the channel to prevent the longitudinal emittance becoming too small and entering a regime in which longitudinal space charge effects are problematic.

- **An Interim Design Report for a Neutrino Factory was completed with substantial contributions from MAP.** The MAP strategy for participating in the international effort to develop the designs and technologies needed for a NF is to focus on the NF R&D that is in common with MC R&D. In practice, this means to focus on the front-end muon source, including how Project X might be upgraded to serve a NF/MC, the target and target area, decay channel, bunching and phase rotation, and the initial ionization cooling channel. In addition, the acceleration for a NF might also serve for the low energy part of a MC acceleration scheme, and MAP studies have therefore contributed to these acceleration studies. Focusing on these things, MAP-supported NF design and simulation studies made significant progress in FY11. In particular (i) the front end channel was shortened and re-optimized, (ii) the magnets and shielding for the pion collection channel were re-optimized as part of an effort to reduce the amount of radiation reaching the superconducting magnets, (iii) a problem was discovered with the large number of protons and electrons in the channel downstream of the target, and simulations were therefore started to understand how to incorporate a chicane in the front end channel to mitigate this effect. An interim design report for a NF was written in FY11 with many contributions from MAP.

4. SUMMARY

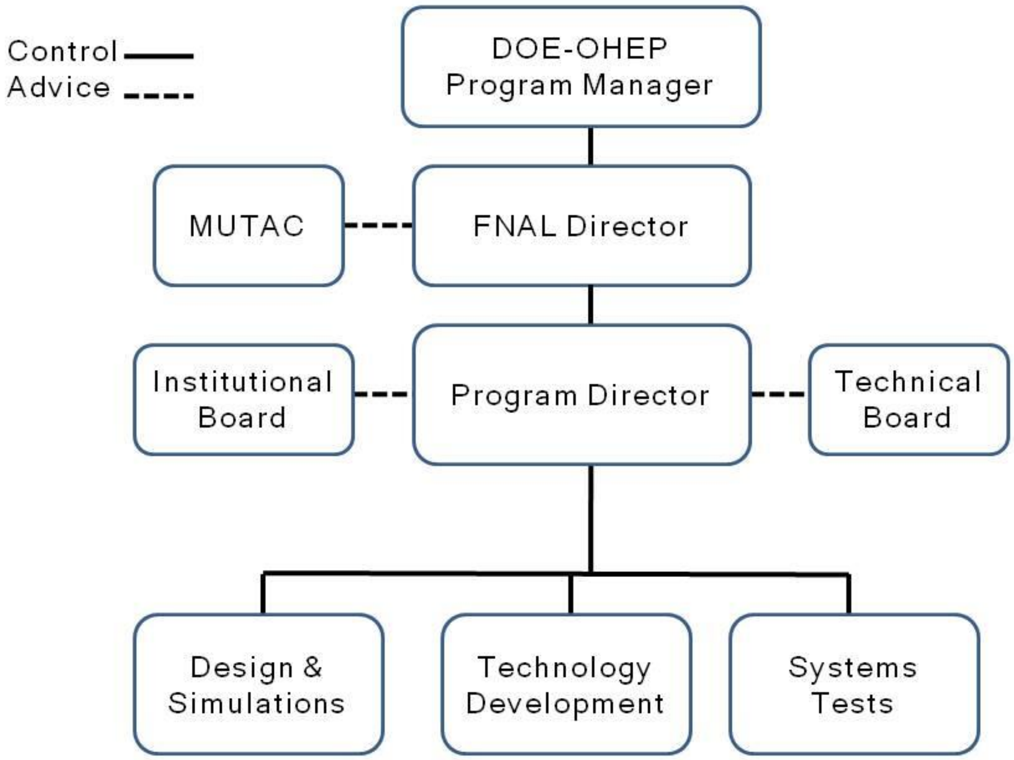
In FY11 the MAP R&D goals have been effectively advanced, with progress ranging from bringing an effective MAP organization into operation, putting MICE magnet repairs on a firm footing, bringing a new beam to the MTA, making substantial progress on the RF-in-magnetic-field studies, progressing on HTS and HCC magnet studies, deepening the understanding of MC component requirements through design and simulation studies, and supporting activities that interface with MC physics and detector studies, Project X studies, and IDS-NF studies.

APPENDIX 1: FY11 RESOURCES

MAP Distribution		FY11	R3					
Institution	RF	Key Design Simulation	MICE Non Magnet	MICE Magnet	Target	Non-MICE Magnet	**SUMS**	Percent
ANL	190						**190**	1.82%
BNL		1315			524		**1839**	17.65%
FNAL	2179	1216	508	657	15	1531	**6106**	58.59%
LBNL	35		200	981			**1216**	11.67%
ORNL					50		**50**	0.48%
SLAC	260						**260**	2.49%
Jlab		10					**10**	0.10%
							0	0.00%
UC-Berkeley	3						**3**	0.03%
UCLA		70					**70**	0.67%
UC-Riverside (*)		22	90				**112**	1.07%
IIT	156		44				**200**	1.92%
U. Mississippi				10		345	**355**	3.41%
Princeton					10		**10**	0.10%
TOTALS	**2823**	**2633**	**842**	**1648**	**599**	**1876**	**10421**	
percent	27.09%	25.27%	22.89%		5.75%	18.00%	100.00%	

(*) Funds were allocated to enable hiring a new post doc. However, the search for a suitable post doc was not successful in FY11, and the funds were not distributed.

APPENDIX 2: ORGANIZATION CHART



APPENDIX 3: MISSION STATEMENT

The mission of the Muon Accelerator Program (MAP) is to develop and demonstrate the concepts and critical technologies required to produce, capture, condition, accelerate, and store intense beams of muons for Muon Colliders and Neutrino Factories. The goal of MAP is to deliver results that will permit the high-energy physics community to make an informed choice of the optimal path to a high-energy lepton collider and/or a next-generation neutrino beam facility. Coordination with the parallel Muon Collider Physics and Detector Study and with the International Design Study of a Neutrino Factory will ensure MAP responsiveness to physics requirements.

APPENDIX 4: PUBLICATIONS

#	Author	Title	Citation
1	R.J. Abrams et al.	Fast Time-of-Flight System for Muon Cooling Experiments	Proc. PAC11 (2011 Particle Accelerator Conference), MOP040, Mar 28-Apr 1, 2011, New York, NY, USA
2	R.J. Abrams et al.	Non-Magnetic Momentum Spectrometer Based on Fast Time-of-Flight System	Proc. PAC11 (2011 Particle Accelerator Conference), MOP038, Mar 28-Apr 1, 2011, New York, NY, USA
3	Y. Alexahin and D.J. Summers	Rapid-Cycling Synchrotron with Variable Momentum Compaction	Proc. IPAC'10, 1st International Particle Accelerator Conference, MOPE085, May 23-289, 2010, Kyoto, Japan
4	Y.I. Alexahin et al.	Muon Collider Interaction Region Design	Phys. Rev. ST Accel. Beams 14 (2011) 061001
5	J. Back et al	Particle production simulations for a neutrino factory target	Proc. IPAC'11, 2nd International Particle Accelerator Conference, Sept 4-9, 2011, San Sebastian, Spain
6	R. Barlow et al	EMMA – The world's first non-scaling FFAG	Nuc. Instrum. Meth. A 624 (2010) 1
7	K.B. Beard, S.A. Bogacz, V.S. Morozov, Y. Roblin	Simulations of a Muon Linac for a Neutrino Factory	Proc. PAC11 (2011 Particle Accelerator Conference), MOP043, Mar 28-Apr 1, 2011, New York, NY, USA
8	J.S. Berg	The EMMA Non-Scaling FFAG Experiment	ICFA Beam Dynamics Newsletter 55 (2011) 92
9	J.S. Berg	A non-scaling Fixed Field Alternating Gradient accelerator for the final acceleration stage of the International Design Study of the neutrino factory	Proc. IPAC'11, 2nd International Particle Accelerator Conference, Sept 4-9, 2011, San Sebastian, Spain
10	J.S. Berg et al.	The International Design Study for the Neutrino Factory	ICFA Beam Dynamics Newsletter 55 (2011) 54
11	S. Blot	Stability of the MICE Muon Beam Line	Proc. PAC11 (2011 Particle Accelerator Conference), MOP061, Mar 28-Apr 1, 2011, New York, NY, USA
12	S. Blot et al.	Proton Contamination Studies in the MICE Muon Beam Line	Proc. IPAC'11, 2nd International Particle Accelerator Conference,

			MOPZ033, Sept 4-9, 2011, San Sebastian, Spain
13	U. Bravar and D. Li,	Length Increase of the RFCC Module	MICE-NOTE-GEN-332
14	S. Choubey et al.	International Design Study for the Neutrino Factory, Interim Design Report	Report IDS-NF-20, submitted to the ECFA neutrino panel (2011)
15	D. Cline, X. Ding, A. Garren, F. Mills	Estimate of the parameters for the injection system into the solenoid/dipole ring cooler and the heating of the cooling absorbs	MAP-doc-#4304, http://map-docdb.fnal.gov/cgi-bin/ShowDocument?docid=4304 (2011)
16	L. Coney and A. Dobbs	Particle Production in the MICE Beam Line	Proc. PAC11 (2011 Particle Accelerator Conference), MOP058, Mar 28-Apr 1, 2011, New York, NY, USA
17	A. DeMello et al.	Progress on MICE RFCC Module for the MICE Experiment	Proc. PAC11 (2011 Particle Accelerator Conference), TUP290, Mar 28-Apr 1, 2011, New York, NY, USA
18	X. Ding et al	Racetrack Muon Ring Cooler Using Dipoles and Solenoids for a Muon Collider	Proc. PAC11 (2011 Particle Accelerator Conference), Mar 28-Apr 1, 2011, New York, NY, USA
19	X. Ding et al	Robust 6D Muon Cooling in Four-sided Ring Cooler using Solenoids and Dipoles for a Muon Collider	Proc. PAC11 (2011 Particle Accelerator Conference), Mar 28-Apr 1, 2011, New York, NY, USA
20	X. Ding, D. Cline, H. Kirk, J.S. Berg	A Pion Production and Capture System for a 4MW Target Station	Proc. IPAC'10, 1st International Particle Accelerator Conference, THPEC092, May 23-289, 2010, Kyoto, Japan
21	X. Ding, D. Cline, J.S. Berg, H. Kirk, A. Garren	Status of Studies of Achromat-based 6D Ionization Cooling Rings for Muons	Proc. IPAC'11, 2nd International Particle Accelerator Conference, MOPZ030, Sept 4-9, 2011, San Sebastian, Spain
22	M. Ellis et al.	The design, construction and performance of the MICE scintillating fibre trackers	Nucl. Instrum. Meth. A (2011), to appear
23	R.R.M. Fletcher, L. Coney, and G. Hanson	Measurement of Neutral Particle Contamination in the MICE Muon Beam	Proc. PAC11 (2011 Particle Accelerator Conference), MOP053, Mar 28-Apr 1, 2011, New York, NY, USA
24	B. Freemire et al.	High Pressure RF Cavity Test at Fermilab	Proc. PAC11 (2011 Particle Accelerator Conference),

			MOP032, Mar 28-Apr 1, 2011, New York, NY, USA
25	A. Garren et al	6D $\mu^{\pm}$ cooling using a solenoid-dipole ring cooler for a muon collider	Nuc. Instrum. Meth. A, to be published
26	S. Geer, M. Zisman	The Muon Accelerator Program	ICFA Beam Dynamics Newsletter 55 (2011) 72
27	Ramesh Gupta et al.	High Field HTS R&D Solenoid for Muon Collider	IEEE Trans. Appl. Supercond. 21 (2011) 1884
28	P.M. Hanlet	Status and Goals of MICE	Proc. XIV Neutrino Telescope Conference, Venice, Italy, March 15–18, 2011
29	T.L. Hart, D.J. Summers, and K. Paul	Magnetic Field Expansion Out of a Plane: Application to Inverse Cyclotron Muon Cooling	http://arXiv.org/pdf/1105.2754
30	T.L. Hart, D.J. Summers, and K. Paul	Magnetic Field Expansion Out of a Plane: Application to Cyclotron Development	Proc. PAC11 (2011 Particle Accelerator Conference), WEP190, Mar 28-Apr 1, 2011, New York, NY, USA
31	C. Johnstone, K. Makino, M. Berz, S. Koscielniak, P. Snopok	Advances in Nonlinear Non-Scaling FFAGs	Int. J. Mod. Phys. A 26 (2011) 1690-1710
32	C. Johnstone, M. Berz, P. Snopok, eds.	Fixed field alternating gradient accelerators. Proceedings, International Conference dedicated to Alessandro G. Ruggiero for his many contributions to the rebirth of the FFAG Fermilab, FFAG'09, Batavia, USA, September 21-25, 2009	Int. J. Mod. Phys. A26 (2011) 1659-1902
33	S.A. Kahn et al.	Beam Induced Detector Backgrounds at a Muon Collider	Proc. PAC11 (2011 Particle Accelerator Conference), THP088, Mar 28-Apr 1, 2011, New York, NY, USA
34	A. Kalinin et al	The EMMA accelerator, a diagnostics systems overview	Proc. IPAC'11, 2nd International Particle Accelerator Conference, Sept 4-9, 2011, San Sebastian, Spain
35	D.M. Kaplan	The MICE Program	ICFA Beam Dynamics Newsletter 55 (2011) 84
36	D.M. Kaplan	From Neutrino Factory to Muon Collider	Proc. 12th International Workshop on Neutrino Factories, Super Beams, and

			Beta Beams, Oct 20-25, 2010, Mumbai, India, AIP Conf. Proc. 1382
37	D.M. Kaplan, T. J. Roberts	Study of Multiple Scattering in High Magnetic FIelds	Proc. NuFact11 (arXiv:1110.1051)
38	G.M. Kazakevich et al.	Multi-purpose 805 MHz Pillbox RF Cavity for Muon Acceleration Studies	Proc. PAC11 (2011 Particle Accelerator Conference), TUP092, Mar 28-Apr 1, 2011, New York, NY, USA
39	H. Kirk et al	A solenoid capture system for a muon collider	Proc. PAC11 (2011 Particle Accelerator Conference), Mar 28-Apr 1, 2011, New York, NY, USA
40	H.G. Kirk et al.	A Solenoid Capture System for a Muon Collider	Proc. PAC11 (2011 Particle Accelerator Conference), TUP265
41	H.G. Kirk et al.	A Solenoid Capture System for a Muon Collider	Proc. PAC11 (2011 Particle Accelerator Conference), TUP265
42	H.G. Kirk, K.T. MacDonald	The Muon Collider Target System	ICFA Beam Dynamics Newsletter 55 (2011) 98
43	K. Lee, D. Cline, A. Garren	Study of Li Lens Channel for Final Muon Ionization Cooling Stage	(MAP note in preparation)
44	D. Li, A. DeMello, S. Virostek, M. Zisman, and D. Summers	Normal Conducting RF Cavity for MICE	Proc. IPAC'10, 1st International Particle Accelerator Conference, THPEA049, May 23-289, 2010, Kyoto, Japan
45	D. Li, R. Palmer, D. Stratakis, S. Virostek, and M.S. Zisman	Progress on a Be Cavity Design	Proc. 12th International Workshop on Neutrino Factories, Super Beams, and Beta Beams, Oct 20-25, 2010, Mumbai, India, AIP Conf. Proc. 1382, LBNL-4191E
46	M.L. Lopes et al.	Studies of High-field Sections of a Muon Helical Cooling Channel with Coil Separation	Proc. PAC11 (2011 Particle Accelerator Conference), TUP172, Mar 28-Apr 1, 2011, New York, NY, USA
47	K. Makino, M. Berz, C. Johnstone	High-Order Out-of-Plane Expansion for 3D Fields	Int. J. Mod. Phys. A 26 (2011) 1807-1821
48	J.A. Maloney	Correcting Aberrations in Complex	Proc. PAC11 (2011 Particle

	et al.	Magnet Systems for Muon Cooling Channels	Accelerator Conference), WEP074, Mar 28-Apr 1, 2011, New York, NY, USA
49	J.A. Maloney et al.	EPIC Muon Cooling Simulations using COSY INFINITY	Proc. PAC11 (2011 Particle Accelerator Conference), MOP050, Mar 28-Apr 1, 2011, New York, NY, USA
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